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(54) Improved blade edge

(57) A blade edge with increased durability and a reduced cut force and a method for manufacturing the same. The blade edge is thickened by depositing a coating or grinding. A thin film having a low coefficient of friction, such as amorphous diamond, is then applied to the edge. An additional layer of a lubricious polymer may then be applied. The resulting blade edge has a significantly reduced cut force over existing razor blades and also has greatly increased durability.

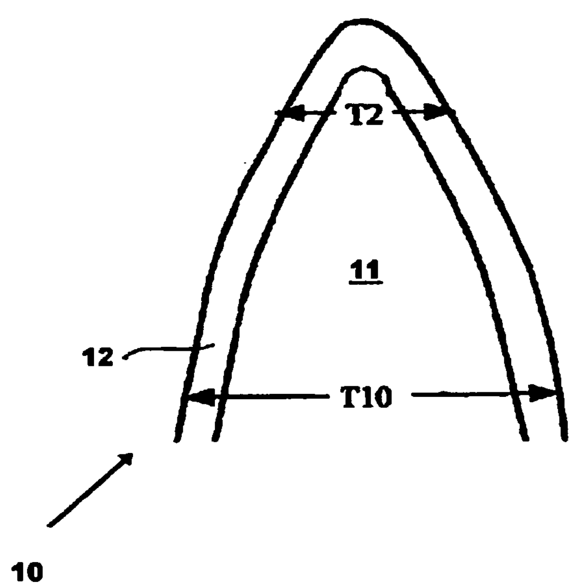

FIGURE 3

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Description

This invention relates to the forming and coating of blade edges to modify the cutting performance of the blade edge.

Razor blade manufacturers have over the years attempted various means of improving shave performance. The primary goal of the manufacturers has been to improve shave performance and comfort by reducing the required cut force and increasing the life of the blade edge. Generally, efforts at improving shave performance and reducing cut force have focused on providing edges with thinner, and theoretically sharper, edge profiles than prevailing blades. Since the thinner edges are weaker than their thicker counterparts, there have been efforts to simultaneously increase the strength of the edge. With regard to cut force, one means of reducing cut force is to modify the geometry of the razor blade edge. It has been found that reducing the width of the blade edge for some distance back from the tip will improve shave performance by cut force reduction. However, reduction in the edge width also weakens the edge and leads to more rapid deterioration due to mechanical deformation during cutting.

A typical razor blade edge has a wedge shape with a preferred included angle of approximately 20 degrees. This wedge may be further characterized by its tip radius, which is the radius of curvature of the ultimate cutting tip, and the thickness of the edge for a distance back from the ultimate tip. Typically, the tip radius is specified as being less than 500Å. The edge thickness is a function of distance from the ultimate edge. For example T2 and T10 may be defined as the width of the edge 2 microns and 10 microns back from the ultimate edge respectively. Typical razor blades have T2 values in the range of from 0.85 - 1.1μ and T10 values in the range of 3.3-4.0μ. Standard mechanical grinding and honing operations give the edge a bit of a convex shape which has been described as a "gothic arch" shape. Most razor blades have a thin layer of chromium on the cutting edge to increase the blade's corrosion resistance and to provide a good base for the application of a lubricating polymer such as polytetrafluoroethylene (PTFE). PTFE has an extremely low coefficient of friction and its use has become virtually universal in the razor blade industry. PTFE (an example of which is sold by duPont under the name KRYTOX 1000) is deposited on the blade edge as a fine powder which is heated above the melt point so that it flows and bonds to the blade edge. The lubricating polymer reduces the force required for the edge to cut through hair. Standard felt cutting tests demonstrate the large reduction in cut force for a PTFE coated edge compared to an uncoated chromium edge.

While the addition of a polymer to the blade edge reduces the cut force, a close look at the ultimate edge of the blade reveals that the ultimate tip is not fully covered by PTFE. Scanning electron microscope (SEM) micrographs show that the molten polymer has a tendency to pull back slightly from the edge. Consequently, polymer coated razor blades contain an uncoated region extending up to a few microns back from the tip of the blade. Therefore, the ultimate tip and cutting point does not benefit from the lubricating effect of the PTFE. It is an object of this invention to improve the lubrication of this small but critical area. It is a further object of this invention to improve the strength of the ultimate tip of the razor blade.

Various means to strengthen the edge, from using harder substrates for blades to the use of hard coatings to strengthen the edge, have been proposed. An example of a substrate that is inherently stronger than the presently used grade of stainless steel is described in U.S. patent 5,121,660 issued to Kramer. Kramer discloses a blade made of a polycrystalline ceramic material which is significantly harder than steel. However, this material is difficult to process and has not yet found commercial application for razor blades.

Hard coatings have been described numerous times as a means of increasing edge strength. For example, U. S. patent 4,933,058 issued to Bache, *et al.* describes the use of ion bombardment during hard coating deposition to achieve a prescribed tip shape. This tip is narrower than standard blades, but retains its strength due to the presence of a thick hard coating on the tip. U.S. patent 5,295,305, issued to Hahn, *et al* discloses the use of a diamond-like carbon (DLC) coating over various adhesion interlayers. The DLC coating is said to provide strength and high quality shaving performance. U.S. patents 5,142,785, issued to Grewal and 5,232,568, issued to Parent, *et al* both describe the use of DLC coatings over a molybdenum adhesion layer. Other patents have similarly disclosed a variety of ceramic coatings applied to strengthen the blade edge.

The modification of edge shape to provide a suitable substrate for hard coatings is disclosed in U.S. patent 5,032,243, issued to Bache, *et al* This patent discloses a method for modifying edge shape through ion beam bombardment. The ion beam removes material from both sides of the facet thus reducing its width. The ion beam method is proposed due to the difficulty in obtaining such blade profiles using mechanical grinding means. However, the ion beam method has its own difficulties and such an arrangement remains to be commercialized.

A somewhat different means of increasing blade life is disclosed in U.S. patent 5,488,774, issued to Janowski. This patent discloses the use of a diamond or DLC coating to reduce shaving degradation due to possible loss of the lubricating polymer during shaving. It is claimed that the PTFE is gradually removed from the edge and that the presence of a low friction coating will minimize the effect of the PTFE removal.

As can be seen, extensive effort has gone into producing thinner and stronger blade edges that minimize cut force while providing normal or extended life. Most

of these methods employ sophisticated means of shaping the blade edge followed by a thick coating of a bard material to strengthen the edge. These methods are difficult to implement and it would be advantageous to produce a blade that has the benefits of a thinner blade edge, i.e. low cut force, but without the attendant strength and production difficulties.

According to a first aspect of the invention there is provided a razor blade as set out in Claim 1.

According to a second aspect of the invention there is provided a razor blade as set out in Claim 14.

According to third and fourth aspects of the invention there are provided methods as set out in Claims 24 and 26.

Preferred features of the invention are set out in the dependent claims.

Consequently, it is an advantage of the present invention to provide such a razor blade and a means for production that avoids much of the difficulty associated with prior designs. Such a blade would advantageously have enhanced strength and durability and exhibit reduced cut forces compared to standard razor blades.

Preferred embodiments of the invention are directed to a blade edge with improved shave performance and a method of manufacturing such blades. To achieve the desired result the tip thickness, tip radius and cut force are increased, either by application of a first, non-polymeric coating or by some other means, and then the blade is coated with a second non-polymeric adherent coating having a very low coefficient of friction. Suitable materials for the second coating include the class of carbon films which include diamond, amorphous diamond, and diamond like carbon (DLC). Another material with a suitably low coefficient of friction is Molybdenum disulfide. The thickness of the coating need only be such that a continuous film, typically less than 500Å, is formed over the blade edge up to and including the ultimate tip. The aspect ratio of this film is approximately 1: 1; there is no need for the high aspect ratios claimed in previous disclosures. The blade is then coated with a lubricating polymer, such as PTFE, as is standard practice in the industry. The resulting blades cut with a significantly lower cut force than comparable blades without the low coefficient of friction film. The blade performs as if the edge were sharper and thinner while retaining the original edge geometry. Because the edge is of at least standard thickness it retains the hardness and durability of a regular edge.

A preferred embodiment of the invention emphasizes edge durability. In this case the edge is made thicker than usual via coating or grinding. Normally the thickening would have the effect of increasing the cut force and compromising shave performance, However, the addition of the coating of this invention reduces the cut force to a nominal level thus restoring shave comfort. Such coated blades last significantly longer and provide better shave performance than their uncoated counterparts by virtue of their thicker and stronger edge.

There now follows a description of preferred embodiments of the invention, by way of non-limiting example, with reference being made to the accompanying drawings in which:

Figure 1 is a chart illustrating the indent depths of blade edges having different coatings. A smaller indent signifies a stronger edge;

Figure 2 is a chart illustrating the effect of the coating of this invention on average cut force for 20 cuts; and

Figure 3 is a schematic representation of a razor blade according to the invention.

Reference will now be made in detail to the presently preferred embodiments of the invention.

The blade edge of the present invention comprises a razor blade having an increased tip thickness and tip radius, a reduced cutting force and a longer usable life. In order to provide these desirable properties, a substrate is provided in which the portion which is to be the cutting edge is prepared with a profile either nominal to or thicker than that of prevailing blades, resulting in increased tip thickness, tip radius, cut force and coefficient of friction. The increased thickness may be achieved in various manners, but a preferred method for achieving this shape is by appropriately grinding or stropping the edge. A further preferred method of producing this shape is by depositing an inner coating of suitable thickness onto the edge of the blade. This coating may consist of virtually any compatible material including oxides, carbides, nitrides, borides, metals and any combinations thereof, preferred materials include ceramics, chromium, chromium/platinum, and chrome nitride. The primary criteria for this coating are that it adheres to the steel substrate and that the coating of this invention adheres to it. In the preferred embodiment a coating of up to 1500 angstroms of chromium is applied to the edge of a ground blade. The actual thickness of the coating may vary depending on a number of variables, including the starting edge shape, and a thicker or thinner coating may be used as desired. The result of the initial thickening step is a blade edge which has increased tip thickness, increased strength, increased tip radius, is less sharp than before and exhibits a correspondingly higher cut force. For example, such a thickened blade edge would be less desirable for cutting hair in that it would tend to "pull" the hair and thus prove uncomfortable during wet shaving.

Once a suitable blade edge is obtained, the edge is coated with an outer coating of a thin film of a non-polymeric material which has a very low coefficient of friction. The outer coating may be deposited by ion beam sputtering, magnetron sputtering, laser beam ablation, vacuum arc deposition, or any other suitable process. The thickness of this non-polymeric coating is preferably less than about 1500 angstroms and an aspect ratio

(tip thickness/flank thickness) of about 1:1 is preferably obtained. In an especially preferred embodiment, the thickness of the non-polymeric coating is in the range of from 100 - 1000 angstroms. A preferred value for the low coefficient of friction is less than about 0.3 and preferably less than 0.2. Preferred materials having such a low coefficient for the thin film coating are amorphous diamond, diamond-like carbon (DLC), molybdenum disulfide, or any other similar material. The preferred thin film coating material is amorphous diamond. Amorphous diamond comprises a nonhydrogenated version of DLC with at least 40% sp3 carbon bonding, a hardness of at least 45 gigapascals and a modulus of at least 400 gigapascals. In contrast, standard DLC has a hardness of only about 30 gigapascals. The resultant blade edge has a further increased tip radius and tip thickness over the blade edge having no coating or the inner coating alone, and has a cut force which is significantly lower than that of the blade edge having the first coating alone. In an especially preferred embodiment, the blade edge may be further coated with a lubricious polymer to further reduce the cut force. Because this coating has been shown to pull back from the edge the presence of the hard, thin film of low coefficient of friction causes the blade to show a significant reduction in cut force over blades having only chromium or other conventional materials on the edge. This superiority of cut force is evident even over sharper blades using conventional coatings. In an especially preferred embodiment, the blade edge is first coated with a thin film having a low coefficient of friction, such as amorphous diamond, and then with a lubricious polymer such as low molecular weight PTFE or KRYTOX 1000 to provide a shave exhibiting minimal cut force. The resulting razor blade is especially advantageous for use with a wet shave razor, and one or more of such blades may be employed in a razor. The blades may be employed in a wet shave razor which is either disposable, i.e. the entire razor is discarded after a certain amount of usage, or permanent which requires disposal and replacement of only the razor cartridge, but not the handle, after a certain number of uses.

A variety of methods are available for depositing the coating of this invention. One method uses pulsed laser deposition to generate a plume of vaporized carbon ions from a solid carbon source. These ions can be directed to the edge of a blade where they will condense as a hard solid film with a suitable low coefficient of friction. Another method is the use of sputtering, either RF or DC, to provide a vapor of carbon atoms which similarly condense onto the blades forming carbon films. Typically, the sputtered films are not as hard as coatings prepared by other means but they may be used due to their low coefficient of friction. CVD methods can be utilized, using a gaseous hydrocarbon gas as the source, but these must be done under conditions where the blades do not exceed 350°C for periods of time as this will soften the blade steel. A preferred method of depositing the carbon films is by the cathodic arc method. Such a method is described fully in patent 5,458,754, assigned to Multi Arc Inc. in New Jersey and the disclosure of that patent is incorporated herein by reference. In this method carbon ions are produced with the arc vaporization of a solid graphite target. The patented method described produces amorphous diamond films with a very low coefficient of friction.

As illustrated in Figure 1, the blade edge which is coated with chromium has significantly increased strength over the uncoated blade edge. Specifically, an unused, standard blade edge will be indented to a depth of approximately 650 nanometers by a 4 gram load applied normal to the blade edge. Coating with 300 Å of chromium increases the edge strength as shown by a reduction in indent depth to about 610 nm, while 600 angstroms of chromium coating further reduces the indents to about 595 nm. A 600 angstrom chromium coating in combination with an amorphous diamond coating of 200-300 angstroms significantly reduces the indent range to approximately 540 nm, thus illustrating that the blade of the present invention is significantly stronger than a standard blade.

Figure 2 illustrates the cut force of a standard blade, a less sharp blade made according to this invention, and a similar less sharp blade including the amorphous diamond coating. All blades are coated per standard process with PTFE. The standard blade edge exhibits a cut force of 2.64 lb. The less sharp blade exhibits an average cut force of 2.96 lb. The addition of 250 angstroms of amorphous diamond to the less sharp blade results in a cut force of 2.46 lb, a significant reduction over the uncoated blade. Consequently, blades made according to this invention are exceedingly durable and will continue to exhibit advantages over conventional blades for hundreds of cuts.

Figure 3 shows a blade edge 10 according to the invention. Blade edge 10 includes a substrate 11 coated with a non-polymer inner coating (not shown separately in Figure 3). The material of the coating may be, for example, Chromium to a thickness of 1500 angstroms. The inner coating if applied on its own to the blade edge 10 would increase the tip radius and the cut force characteristic of the blade edge 10 to higher values than those of conventional blade edges.

Blade edge 10 also includes an outer coating 12 of a further material having a low coefficient of friction relative to eg. human or animal skin. The outer coating 12 increases the tip radius and tip thickness still further compared with a conventional blade, yet provides for a lower cut force.

The outer coating 12 may be of a material as specified herein.

The blade edge 10 is preferably manufactured in accordance with the method of the invention.

While there have been described what are presently believed to be the preferred embodiments of the present invention, those skilled in the art will realize that

various changes and modifications may be made to the invention without departing from the spirit of the invention, and it is intended to claim all such changes and modifications as fall within the scope of the invention.

Claims

1. A razor blade comprising a substrate having a cutting edge which has a first tip radius and first tip thickness and an initial cut force, coated with a non-polymer inner coating of a first material sufficient to increase the initial cut force and provide a second, increased tip radius, a second, increased tip thickness and increase the strength of the cutting edge, and a non-polymer outer coating of a second material having a low coefficient of friction, wherein the second coating provides a third tip radius which is greater than the second tip radius, a third tip thickness which is greater than the second tip thickness and a cut force which is less than the initial cut force, and wherein the first and second materials are different from each other.

2. A razor blade according to claim 1, wherein the first material is selected from the group consisting of oxides, carbides, nitrides, borides, metals, chromium, ceramics, chromiun/platinum, chrome nitride and combinations of this group.

3. A razor blade according to claim 2, wherein the first material is chromium.

4. A razor blade according to claim 2 or claim 3, wherein the inner coating is up to 1500 angstroms thick.

5. A razor blade according to any preceding claim, wherein the second material comprises a non-polymer material sufficient to reduce the coefficient of friction of the substrate.

6. A razor blade according to claim 5, wherein the second material has a coefficient of friction of less than about 0.3.

7. A razor blade according to any preceding claim, wherein the second material is selected from the group consisting of amorphous diamond, DLC (diamondlike carbon), and molybdenum disulfide.

8. A razor blade according to claim 7, wherein the second material is amorphous diamond.

9. A razor blade according to claim 8, wherein the amorphous diamond coating is in the range of about 100 to about 1000 angstroms thick.

10. A razor blade according to any preceding claim further comprising a third coating consisting of a lubricious polymer.

11. A razor blade according to claim 10, wherein the lubricious polymer is polytetraflouroethylene or KRYTOX.

12. A razor blade according to claim 9 or any claim dependent therefrom, wherein the aspect ratio is about 1:1.

13. A wet shave razor comprising at least one blade according to any preceding claim.

14. A razor blade comprising a substrate having a cutting edge that has been increased in width and tip radius sufficient to increase the cutting force and a non-polymer coating sufficient to further increase the tip width and tip radius and to reduce the cut force of the cutting edge.

15. A razor blade according to claim 14, wherein the cutting edge is increased in tip radius and width via grinding or stropping.

16. A razor blade according to claim 14 or claim 15, wherein the coating comprises a non-polymer material having a coefficient of friction of less than about 0.3.

17. A razor blade according to any of claims 14 to 16, wherein the coating is selected from the group consisting of amorphous diamond, diamondlike carbon, and molybdenum disulfide.

18. A razor blade according to claim 17, wherein the coating is amorphous diamond.

19. A razor blade according to claim 18, wherein the amorphous diamond coating is in the range of about 100 to 1000 angstroms thick.

20. A razor blade according to any of claims 14 to 19 further comprising a second coating consisting of a lubricious polymer.

21. A razor blade according to claim 20, wherein the coating is polytetraflouroethylene or KRYTOX.

22. A razor blade according to claim 19, wherein the aspect ratio of the amorphous diamond coating is about 1:1.

23. A wet shave razor comprising at least one blade according to any of claims 14 to 22.

24. A method for manufacturing a razor blade having a cutting edge, comprising the steps of

a) providing a substrate;

b) coating the cutting edge of the razor blade with a first, non-polymer coating which is sufficient to increase the tip thickness, tip radius and cut force of the cutting edge, and

c) coating the cutting edge of the razor blade with a second, non-polymer coating which is sufficient to increase the tip radius and tip thickness of the cutting edge and to reduce the coefficient of friction of the cutting edge.

25. A method for manufacturing a razor blade according to claim 24, comprising the additional step of coating the cutting edge of the razor blade with a lubricious polymer.

26. A method for manufacturing a razor blade having a cutting edge, comprising the steps of

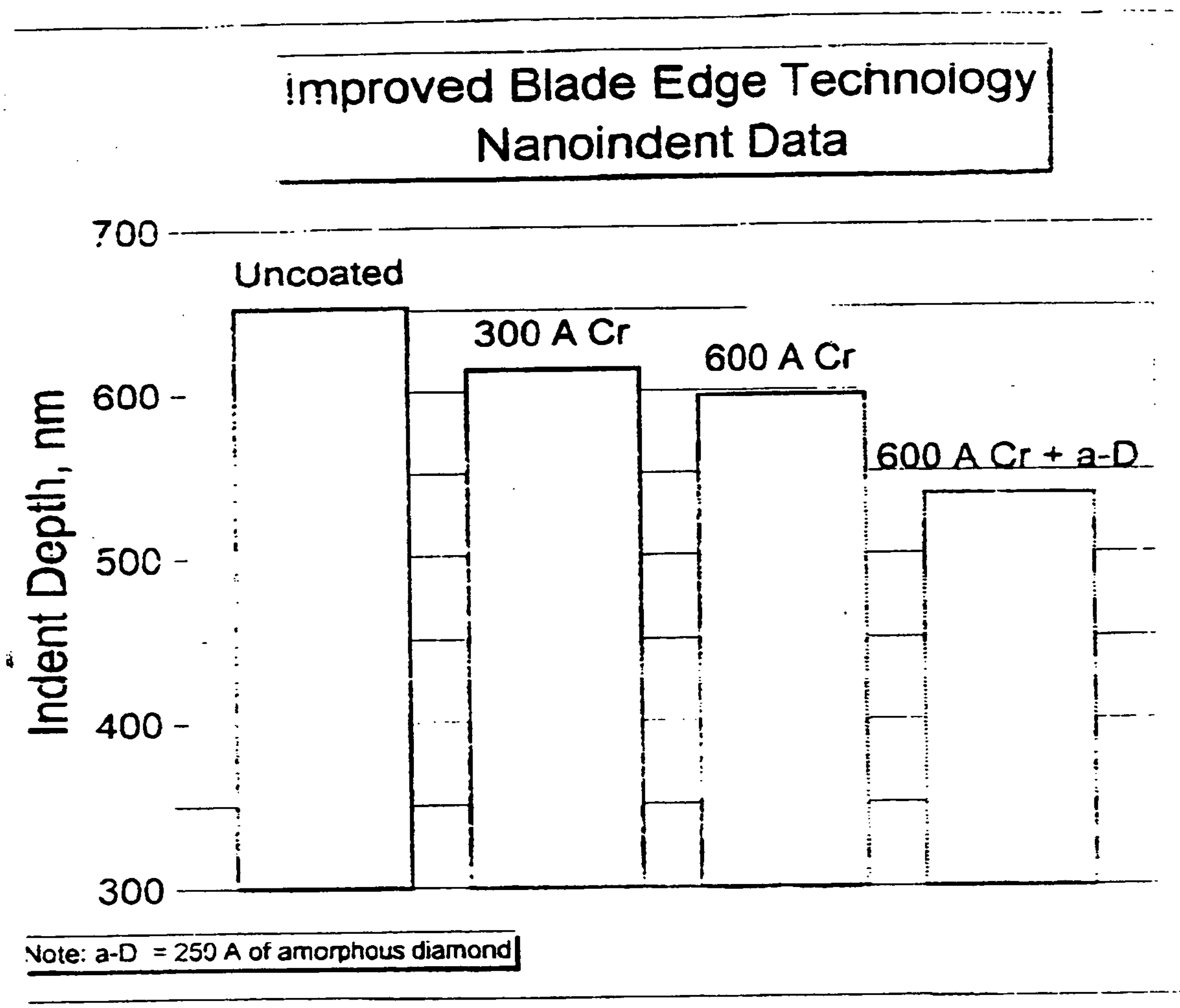
a) providing a substrate;

b) thickening the cutting edge of the razor blade sufficiently so as to increase the cut force of the blade,

c) coating the cutting edge of the razor blade with a non-polymer coating having a low coefficient of friction sufficient to increase the tip thickness and tip radius of the cutting edge and to reduce the cut force of the edge.

27. A method for manufacturing a razor blade according to claim 26, wherein the thickening step is performed via grinding or stropping.

28. A method for manufacturing a razor blade according to claim 26 or claim 27, comprising the additional step of coating the cutting edge of the razor blade with a lubricious polymer.



Improved Blade Edge Technology
Nanoindent Data
700
600
500
400
300
Indent Depth, nm
Uncoated
300 A Cr
600 A Cr
600 A Cr + a-D
Note: a-D = 250 A of amorphous diamond

Figure 1

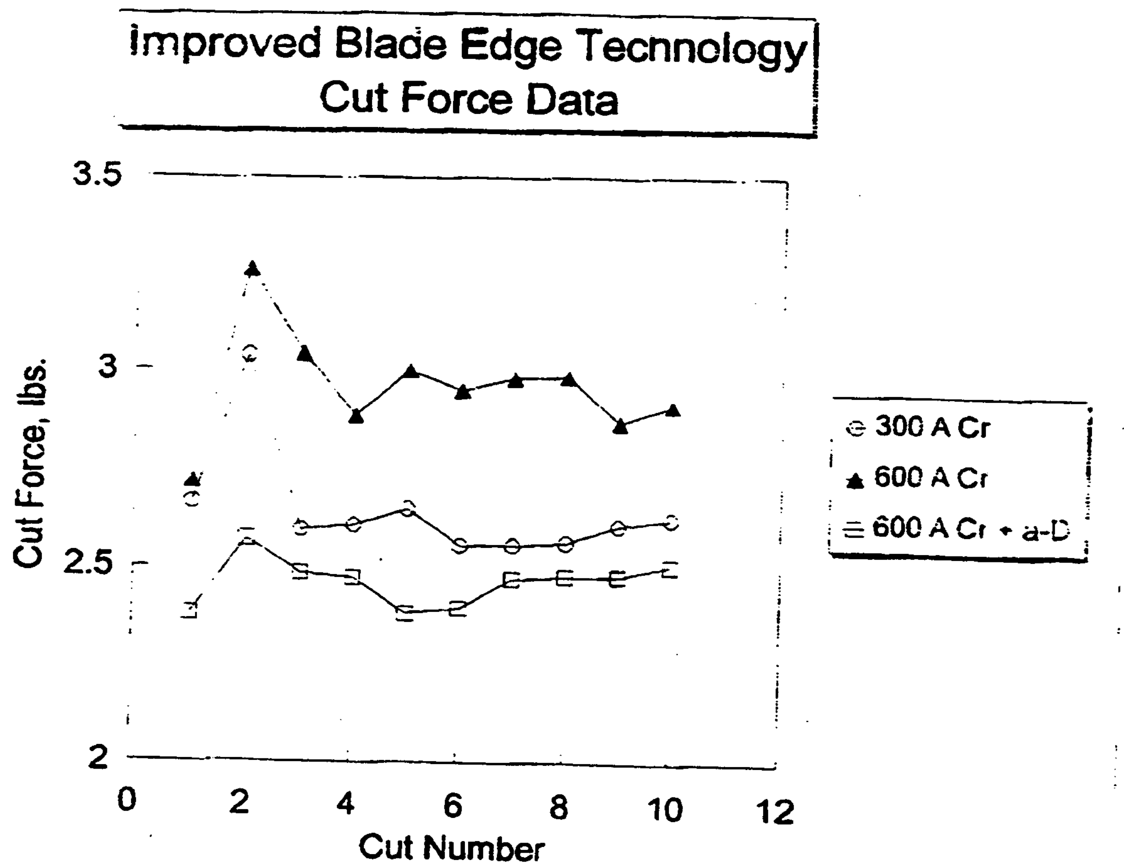

Improved Blade Edge Tecnnology
Cut Force Data
3.5
3
2.5
2
Cut Force, lbs.
0
2
4
6
8
10
12
Cut Number
300 A Cr
600 A Cr
600 A Cr + a-D

Figure 2

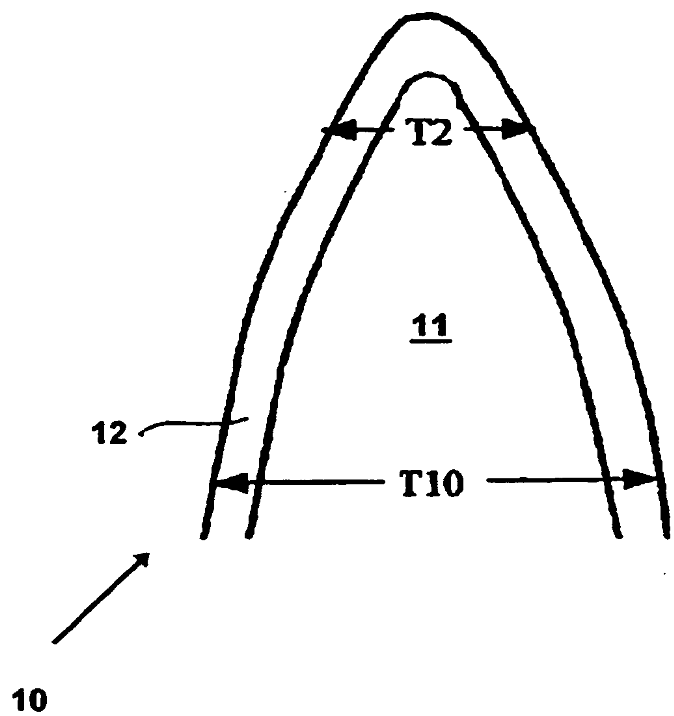


FIGURE 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 30 4533

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	WO 84 02104 A (GLASSON EDWIN LLOYD PERSONAL R ;KOZLOWSKA JADWIGA PERSONAL REP (GB) 7 June 1984 * page 4, line 24 - page 5, line 13 * * page 6, line 13 - line 29; figures 10,10A *	14,15, 20,26-28	B26B21/60 B26B21/54
A	WO 95 29044 A (GILLETTE CO) 2 November 1995 * page 8, line 26 - page 9, line 8; claim 9; figure 3 *	1,14,24, 26	
A	DE 34 03 196 A (DAHLBERG REINHARD) 1 August 1985 * the whole document *	1,14,24, 26	
A	US 5 295 305 A (HAHN STEVE S ET AL) 22 March 1994 * the whole document *	1,14,24, 26	
A	US 5 232 568 A (PARENT C ROBERT ET AL) 3 August 1993 * the whole document *	1,14,24, 26	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	US 5 121 660 A (KRAMER CAROLYN M) 16 June 1992 * the whole document *	1,14,24, 26	B26B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	15 September 1998	Herygers, J

CATEGORY OF CITED DOCUMENTS

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